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CFD Analysis On Double Pipe Hair-Pin Heat Exchanger With Different Nano Fluids

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Abstract: **Heat exchangers are the most commonly used equipment to transfer thermal energy between two fluids. Transfer of heat can be done either direct or indirect contact between the fluids. Mostly indirect counter-current flows heat exchangers are have been used to transfer maximum energy. They are so many factors that are also being affected on transfer of energy in heat exchanger. Such as geometry of the heat exchanger, flow velocities of the fluids, material used for the solid and fluid flows in it.**

In this paper we focused on the improvement of the heat transfer rate in a double pipe hair-pin heat exchanger by varying the fluid materials. Generally water is used to transfer the heat. Because of the low thermal conductivity of water we are adding different solid nano particles to increase the thermal conductivity called nano fluids. Now we consider aluminum oxide (Al_2O_3) and titanium carbide (TiC) nano fluids at different volume fractions (0.1, 0.2 & 0.25) to observe the heat transfer characteristics and compared with ethylene glycol ($C_2H_6O_2$) from journal.

I. INTRODUCTION

The device which mainly used to transfer the thermal energy between hot fluid and cold fluid with maximum rate, less investment and at low cost are named as heat exchangers. Heat exchangers are named as different manners by considering the purpose of utility of it. For example, heat exchangers being used to condense is known as condensers, similarly heat exchanger for boiling purposes are called boilers.

A. Double Pipe Hair-Pin Heat Exchanger:

Double pipe hair-pin heat exchanger is the one of type in tubular heat exchanger and is expressed as a single pass shell and tube heat exchanger. It is extended to the required length and bend like hair pin shape at the edges. This heat exchanger consists of pair of concentric tubes. One of the fluid flows in the inner tube and other fluid flows in the annuls space between them. Double Pipe heat exchangers are mostly suitable for extreme temperature crossing, high pressure, high temperature, and low to moderate surface area requirements.

B. Nano Fluids:

A nano fluids is a new kind of heat transfer medium, containing nano sized particles which are uniformly and stably distributed in the base fluid. The particles used in nano fluids are generally metal, metal oxides and carbides mixes with the base fluids either water, ethylene glycol and oil. Increasing the thermal conductivity of the working fluid is the one of the method employed to improving the heat transfer efficiency. Most commonly used heat transfer fluids (water, ethylene glycol) have relatively low thermal conductivity compared to solids. Thermal conductivity of these fluids can be increased my mixing with the high thermal conductivity solids. The size of these the solid particles used are in the order of 2 millimeters or micrometers. If the size of the particles more than these clog the flow channels, Pressure drop in the fluid increases are to be faced.

There are different types of nano fluids are used with water as the base fluid. Examples are Al_2O_3+ water, SiO_2+ water, TiO_2+water, CuO+ water, TiC+ water, ZnO+ water etc. among these we consider Al_2O_3+water and TiC+ water as our nano fluids used in the heat exchanger as a cooling fluid. Thermal properties of these nano fluids at different volume fractions are:

Nano fluid	Volume fraction (%)	Density (kg/m3)	Specific heat (j/kg-k)	Termal conductivity (w/m-k)	Viscosity (kg/m-s)
ALUMINIUM OXIDE	0.1	1286.38	3195.1	1.01	0.0125375
	0.2	1574.56	2569.4	1.844	0.0015045
	0.25	1718.6	2335.29	1.928	0.00162987
TITANIUM CARBIDE	0.1	1391.2	2952.5	1.02	0.00125375
	0.2	1784.4	2264.4	1.95	0.0015045
	0.25	1981.15	2022.6	2.9	0.0016298

Table 1: properties of nano fluid at different V.F

II. LITERATURE REVIEW

M Kumar (2015) Conducted experiments on the enhancement of heat transport in laminar and turbulent flow of varying composition of ethylene glycol mix with water in double tube hair-pin heat exchanger. Obtained results indicated that the heat transfer coefficient of a mixture of ethylene glycol and water increases with Re number and ethylene glycol concentration. [1]

Kaderi Deepika (2015) performed experiment on double pipe heat exchanger with galvanized pipe and copper pipes are the materials of the tubes with water as the working fluid in both pipes. From this overall heat transfer coefficient in both parallel and counter flows are calculated and compared. Finally concluded that counter flow heat transfer is better than parallel flow. [2]

W H Azmi et al (2011) proved that the values obtained from the non linear regression equations used to determine the density, specific heat, thermal conductivity and viscosity are having the same results by performing the experiment with Al_2O_3, TiO_2 , ZnO are different nano fluids with different particles diameters.[3]

Dhiraj Tiwar (2015) investigated effects of temperature and flow characteristics on a horizontal double tube counter flow heat exchanger under turbulent flow with Al2O3 nano fluid at(0.1–3) %.The results shows that the convective heat transfer coefficient of nano fluid is slightly higher than that of the base liquid at same mass flow rate and At same inlet temperature, heat transfer coefficient of the nano fluid increases with an increase in the mass flow rate, also the heat transfer coefficient increases with the increase of the volume concentration of the Al2O3 nano fluid.[4]

Mohamed hadi et al: Studied enhancement of heat transfer rate by considering clustering effect of nano particle. The heat transfer rate is increases with increasing the concentration of nano particle, due to high concentration clustering is occur. Clustering is increased the heat transfer rate of Nano fluid at certain contact time of particle, but cluster still possess the problem of agglomeration. Agglomeration can reduce to use micro sized particle.[5]

III. CFD ANALYSIS-EXPERIMENTAL SETUP:

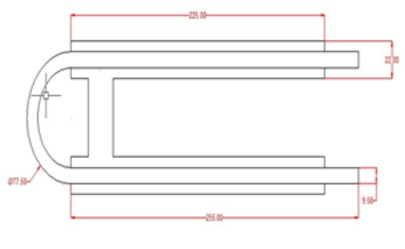
A. CFD PROCEDURE:

They are so many factors that are also being affected on transfer of energy in heat exchanger. Such as geometry of the heat exchanger, flow velocities of the fluids, material used for the solid and fluid flows in it.

Thermal performance of a heat exchanger can be increased by changing the any of the techniques such as geometry of the heat exchanger, flow velocities of the fluids, material used for the solid and fluid flows in it. In the present study we does not concentrate on the changing the geometry of heat exchanger, flow velocities of the fluids. Coming to the materials used, we are considered different nano fluids with different volume fractions. Basically water, ethylene glycol & oil are used to carry the heat from the hot fluid. Because of the low thermal properties of these fluids they can't transfer heat in an effective manner. By adding the nano sized solid particles to the base fluids with different fractions increase the thermal properties of the fluids and finally increase the heat transfer rate. Based on this point we consider two nano fluids (Al_2O_3+ water), (TiC+ water) at different volume fractions instead of ($C_2H_6O_2$+ water) used in the base journal at the same volume fractions.

To study this first we have to know the different thermal properties of the ethylene glycol nano fluid at different volume fractions. The following steps are to be followed to determine the properties of fluids at any volume fraction.

1. Generate the geometry by using PRO/ENGINEER software with the defined dimensions and import to ANSYS.
2. Meshing is done by giving named selections and sizing done by dividing the geometry into 40480 tetrahedron elements.
3. In the Set-up tool apply the boundary conditions of the geometry as follows:
   a. **In the General tab** Pressure based solver was taken as basic type because the density of the total fluid flow inside the channel is taken as constant. Steady analysis is carried out as the flow varies without time.
   b. **In the Models tab** Energy is switched ON and flow takes place. Viscous model is taken as k-epsilon standard wall function.
   c. **In the Materials tab** Fluid is taken as water-liquid and ethylene glycol nano fluid as primary and secondary fluids and copper and galvanized iron is taken as material for the analysis.
   d. **In the cell zone conditions tab** assign the type of phase to the given named selections and give the materials to it either solid or liquid.
   e. **In the Boundary conditions tab** Mass flow rate (kg/s) and temperatures (^{0}C) of the primary and secondary fluids are given as the input parameters at the inlets of the cold fluid and hot fluids respectively. Cold fluid is considered at 30^{0}C& flows at 1-5 lit/min and hot fluid is considered at 70^{0}C& flows at 3 lit/min at 0.1, 0.2 & 0.25 volume fractions.



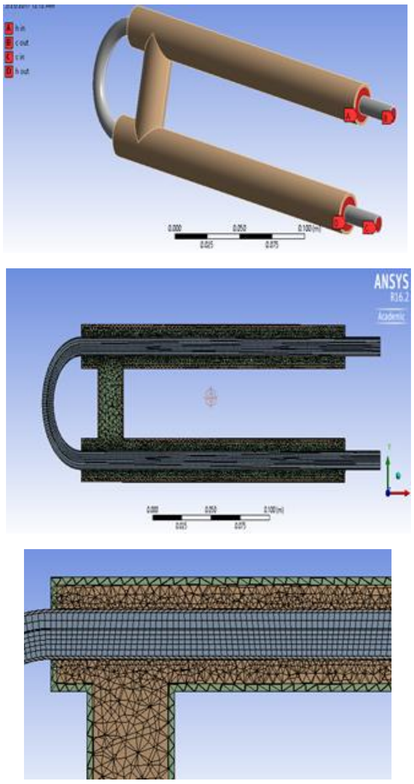


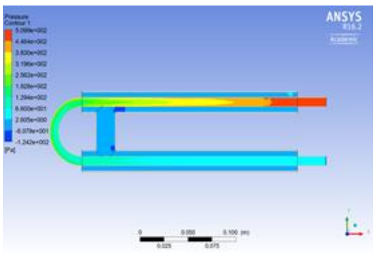
Figure 1: CFD analysis on experimental setup.

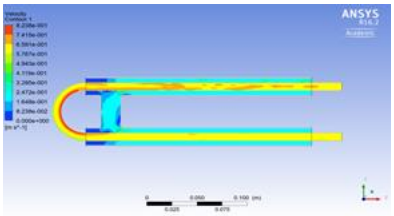
Volume fraction (%)	Mass flow rate (kg/sec)	H.T Coeff.of cold fluid (W/m^2-K)	Velocity (m/sec)	Pressure (N/m^2)	Temp. (K)	Heat transfer Rate (W)	Max heat transfer coeff. (W/m^2-K)
0.10	0.0255	1594.87	0.581	448.00	343	98516	6492
	0.034	***2109.92***	***0.823***	***510.00***	***343***	***110751***	*7789*
	0.0425	2462.582	0.99	615.00	344	139921	10026
	0.051	3044.546	1.21	922.00	343	140026	11068
	0.0646	3308.448	1.54	1184.00	343	165397	13139
0.20	0.0289	2501.75	0.64	441.00	343	1109452	6502
	0.034	***3311.99***	***0.79***	***750.00***	***343***	***112706***	*7799*
	0.0408	3769.54	0.95	628.00	343	121830	*8854*
	0.0459	4518.25	1.039	869.00	343	157588	10512
	0.051	4859.84	1.185	1270.00	344	181045	11123
0.25	0.0221	2659.74	0.478	235.00	343	87365	4674
	0.0255	3286.98	0.564	308.00	344	102495	5354
	0.0289	3985.27	0.649	453.00	343	110019	6479
	0.032	***4341.7***	***0.787***	***617.00***	***343***	***115124***	*7777*
	0.0357	4971.97	0.82	692.00	343	125754	8068

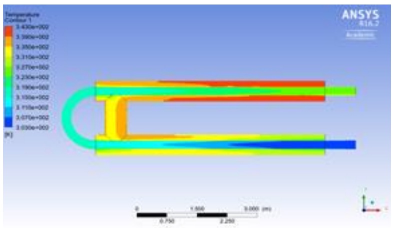
Table 2: Thermal properties of ethylene glycol nano fluid at different flow rates and different V.F

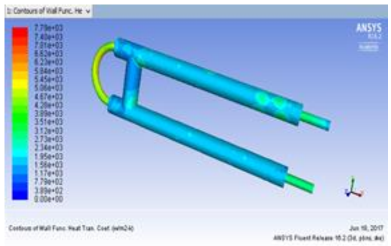
It is difficult to show the results of all properties at different flow rates along with different volume fractions we consider one preferable flow rate (2lit/min) at 0.1 V.F

B. CFD RESULTS:









```
Total Heat Transfer Rate                (w)
---------------------------- -------------------
                        c_in          657.48828
                       c_out         -1242.6528
                        h_in          9562.7178
                       h_out         -8893.4678
                     wall-27          577.53076
              wall-27-shadow         -574.20972
                     wall-28          563.63971
              wall-28-shadow         -565.13135
                      wall-6          110377.66
               wall-6-shadow            288.159
            ---------------- -------------------
                         Net          110751.74
```

```
Wall Func. Heat Tran. Coef.           (w/m2-k)
------------------------------ -----------------
                       c_fluid         2109.9211
              ---------------- -----------------
                           Net         2109.9211
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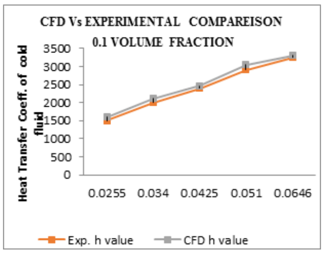
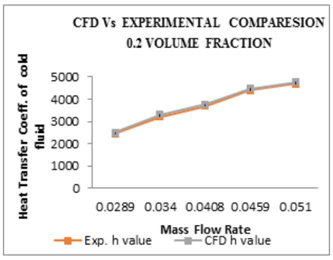
Figure 2: Thermal properties of Ethylene glycol nano fluid at 0.1 V.F

C. COMPARING EXPERIMENTAL & CFD RESULTS:





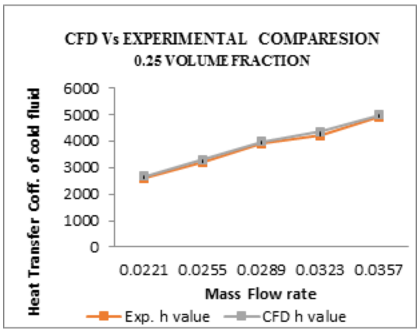


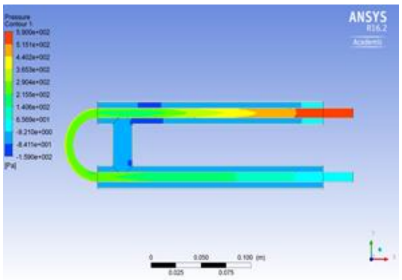
Figure 3: Comparing experimental and CFD results.

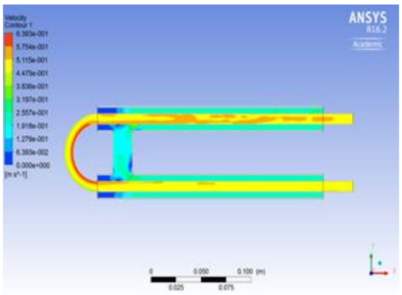
By observing the experimental and CFD results those are very closer to each other, this says that the performance done in the CFD is accurate and it can be used as a tool for find out the results of any others.

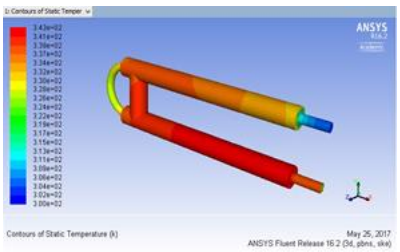
IV. CFD RESULTS WITH NEW NANOFLUIDS

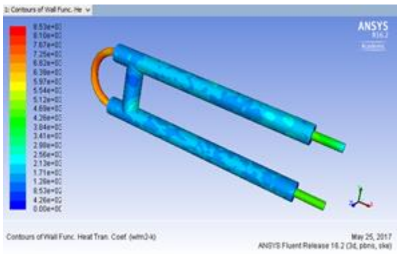
Thermal properties of aluminum oxide and titanium carbide nano fluids at different volume fractions can be determined by the same procedure which is followed in CFD to compare the experimental results. By considering the boundary condition as cold fluid is considered at 30^0C & flows at 2 lit/min and hot fluid is considered at 70^0C & flows at 3 lit/min.

A. Al_2O_3 nano fluid at 0.1 volume fraction.





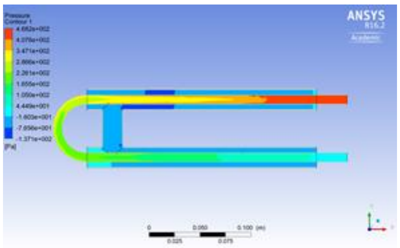


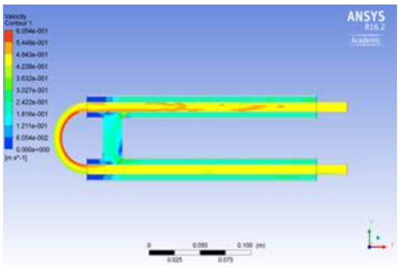


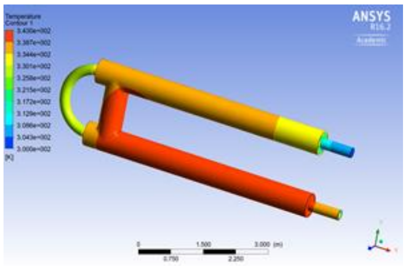
Total Heat Transfer Rate	(w)
c_in	423.69342
c_out	-1387.2925
h_in	13826.713
h_out	-12624.837
wall-27-shadow	-974.61523
wall-28	951.69525
wall-28-shadow	-953.89716
wall-6	155210.23
wall-6-shadow	401.38379
Net	154873.08

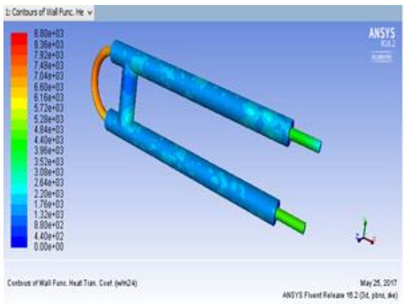
Figure 4: Thermal properties of Al_2O_3 nano fluid at 0.1 V.F

B. TiC nano fluid at 0.1 volume fraction.









Total Heat Transfer Rate	(w)
c_in	486.86673
c_out	-1112.7423
h_in	9562.6602
h_out	-8274.9121
wall-27	625.42804
wall-27-shadow	-622.9574
wall-28	608.8595
wall-28-shadow	-609.73755
wall-6	110940.45
wall-6-shadow	285.52026
Net	111889.43

Figure 5: Thermal properties of TiC nano fluid at 0.1 V.F

RESULTS

We are using aluminum oxide and titanium carbide nano fluids with varying volume fractions of 0.1, 0.2 & 0.25 with base fluid of water in a double pipe heat exchanger. After analysis we observe that thermal properties (velocity, pressure, heat transfer coefficient, hear transfer rate) of nano fluids increase with increasing the volume fraction. And also we have observed that at the same volume fraction aluminum oxide have more result values compared to titanium carbide.

Material	Volume fraction	Velocity	Pressure	Heat transfer coefficient	Temp.	Heat transfer
	(%)	(m/sec)	(N/m2)	(W/m2-K)	(K)	(W)
ALLUMINIUM OXIDE	0.1	0.639	590	8530	343	154873
	0.2	0.534	310	11300	343	167582
	0.25	0.475	219	12700	343	177950
TITANIUM CARBIDE	0.1	0.605	468	8800	343	111889
	0.2	0.453	311	10200	343	122569
	0.25	0.402	232	12900	343	128247

Table 3: CFD results with two nano fluids at three volume fractions

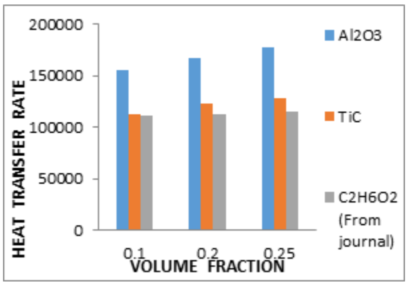


Figure 6: Comparing the maximum rate of heat transfer of two nano fluids with ethylene glycol

V. CONCLUSION

From the results we can conclude that thermal properties of nano fluids are increases with the increase of the volume fractions.

By seeing the result table, among the two different materials at three concentrations we get the maximum heat transfer rate occur at aluminum oxide nano fluid at 0.25 volume fraction. And from the graphical comparison of the heat transfer rate of aluminum oxide and titanium carbide with the ethylene glycol, aluminum oxide has maximum value. From this we conclude that the performance of the heat exchanger will be better when Al_2O_3 nano fluid as the working fluid compared with the other two fluids.

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